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THE OPPORTUNITIES FOR AND CHALLENGES OF COMMON INTEGRATED ELECTRONICS

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February 1994

Prepared for
Office of the Deputy Under Secretary of Defense
(Acquisition and Technology)/Tactical Warfare Programs

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This document summarizes a portion of IDA's work concerning common integrated electronics and the potential cost savings of using common electronic hardware and software. It addresses trends in avionics costs and recent experiences in applying common electronic standards to weapon programs as a way to reduce costs. The following essential elements of a program to acquire common integrated electronics are explored: integrated system architecture, advanced technology programs, open system standards, standard common modules, and associated management and policies. The principal recommendation is that OSD support and coordinate such a program by taking a strong leadership role and setting standards policy.

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) for the Office of the Under Secretary of Defense (Acquisition and Technology)/Tactical Warfare Programs to summarize a series of studies related to the cost-effectiveness of common integrated electronics. It summarizes the outcomes of these prior studies and recommends an approach for future acquisition of electronics to achieve life-cycle cost savings. Although the previous studies focused mainly on avionics, the conclusions drawn should apply equally to most weapon system electronics.

This document was reviewed by Bruce R. Harmon, Waynard C. Devers, and Richard R. Legault.

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I. INTRODUCTION AND SUMMARY

A. INTRODUCTION

Electronic equipment is becoming an increasingly costly part of the Department of Defense's weapon and support systems. Such equipment is pervasive in information/business systems, and command, control, communications and intelligence (C^3I) systems, as well as weapon systems. The cost of avionic equipment for the F-22 tactical fighter aircraft is expected to average more than $10,000 per pound, which could total as much as one-third of the total aircraft flyaway cost.

The Institute for Defense Analyses (IDA) has supported the Office of the Under Secretary of Defense (Acquisition and Technology)/Tactical Warfare Programs by conducting a series of studies (References [1 through 6]) that examined the application of common integrated architectures and modular hardware and software to Department of Defense (DoD) electronic systems. These studies showed that application of these concepts can reduce the costs of acquiring and supporting electronic systems. Among the potential benefits are:

- reductions in development cost due to avoidance of development duplication,
- savings in production cost due to the increase in production quantities of common items and the attendant decrease in per-unit cost,
- reductions in operating and support (O&S) costs due to avoidance of duplicating maintenance resources, spares, and support equipment,[1] and
- savings in aircraft life-cycle cost due to decreases in system weight and volume.

The DoD and the military services realize the importance of using integrated system architectures as a means of saving costs during a period of decreasing defense budgets. The Joint Integrated Avionics Working Group (JIAWG) was established by the DoD in response to a congressional mandate to develop and apply common integrated electronics to the F-22, the RAH-66, the A-12 Pre-Planned Product Improvement (P^3I), and their

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1 O&S cost reductions are considered to be a likely consequence of commonality, but were not addressed by the IDA studies.

variants.[2] JIAWG has achieved some success in securing use of integrated system concepts and common modules within the individual F-22 and RAH-66 programs.

There are examples of common avionic equipment in the military services. The Joint Services Review Committee (JSRC) was chartered by the Joint Logistics Commanders to address avionics standardization. JSRC has developed several pieces of navigation equipment that have been used as a standard across the three services. The Navy has a standard computer program (AYK-14) for weapons programs that has been successful in both air and sea environments.

The DoD and other government agencies are currently developing information processing standards. However, the private sector, which dominates the computer processing market, is in the forefront of developing new technology and establishing standards through organizations such as the Institute of Electrical and Electronics Engineers (IEEE), the American National Standards Institute (ANSI), and the Society of Automotive Engineers (SAE). The DoD has made use of the private sector's information processing technology and standards for information/business and C^3I systems, but little use has been made of such technology and standards for weapon systems that require real-time processing.

To secure maximum benefit from common integrated electronic architectures, it is essential that comprehensive standards, technology, and management programs be applied. This document explores DoD's experiences in developing and applying common integrated electronics, and presents the essential elements needed to initiate a comprehensive program for acquiring common integrated electronics within the DoD.

B. SUMMARY

IDA's previous studies on this subject [1 through 6] explored trends in avionics costs, the effect of integrated system architectures on costs and aircraft characteristics, the role of advanced technology, the application of open systems standards, the use of equipment commonality, and the management environment necessary to achieve further progress in applying common architectures and equipment to defense system acquisition.

The overall conclusion drawn from these studies was that one way of controlling electronic system costs would be to implement a comprehensive common integrated architecture program. We recommend that such a program encompass the following

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2 The A-12 program was canceled in 1991 and replaced by the A/F-X, which was briefly considered before it, too, was canceled.

essential elements: integrated system architecture, advanced technology programs, open system standards, standard common modules, and associated management and policies.

Such a program requires proper coordination. We further recommend that the Office of the Secretary of Defense (OSD) take a strong role in both setting standards policy and in approving those standards that will affect all of DoD.

II. BACKGROUND

As part of the 1987 DoD Appropriations Act Conference Report [7], the U.S. Congress required that the DoD initiate action to use common integrated electronics to reduce aircraft acquisition costs. This chapter reviews trends in avionic cost and the DoD's response to the congressional mandate. It also explains recent efforts to apply common electronic standards to weapon programs and describes the management environment for achieving common electronic standards.

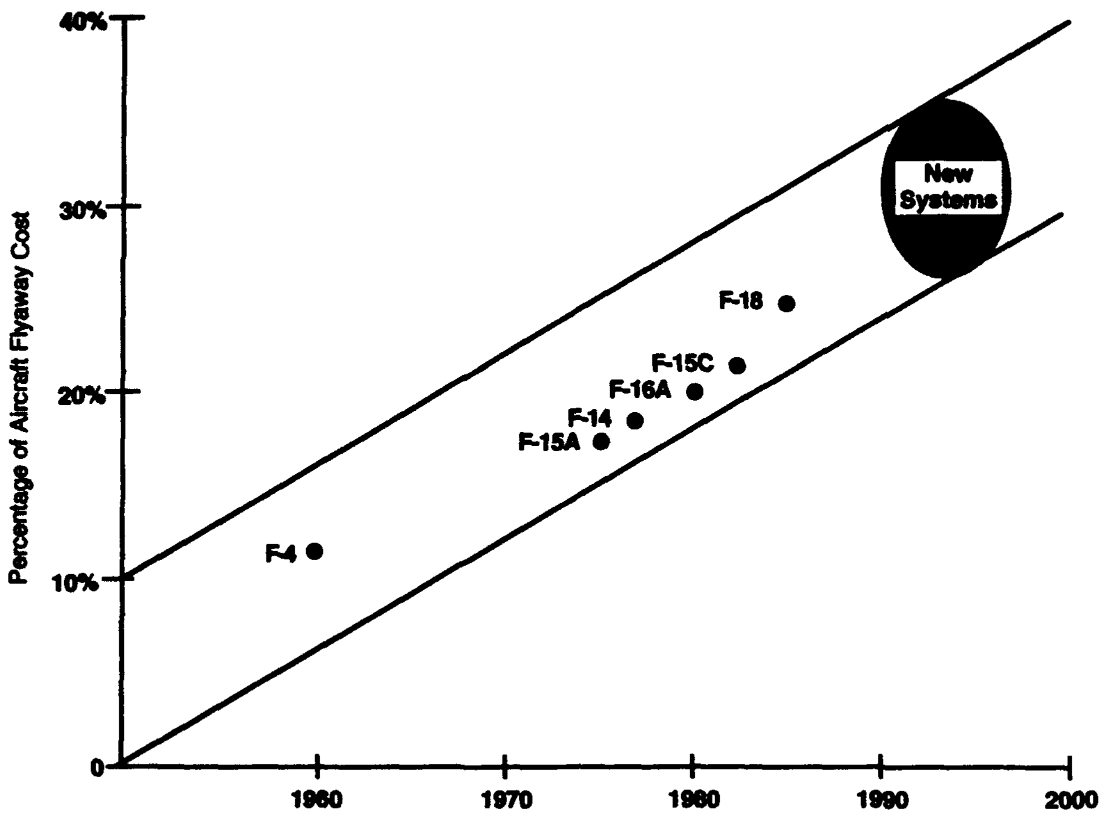
A. AVIONIC COST TRENDS

The percentage of aircraft flyaway cost devoted to avionic equipment has been rising steadily over the past forty years (see Figure II-1). In 1960, avionics represented approximately 10 percent of the total aircraft flyaway cost. In the year 2000, the cost of avionics for the F-22 aircraft is expected to be about one-third of the aircraft flyaway cost. In the interim aircraft costs have risen by over a factor of 10, and the costs of avionics have increased at an even faster rate.

Computer components make up a significant part of current avionics. The commercial cost of these components has fallen by a factor of 10 over each of the past several decades. This decrease should have led to lower avionic processing costs; unfortunately, that has not happened.

The dramatic cost increase in avionics has resulted from a combination of factors. Principal among them are the increased functionality required of avionic systems, the added cost of integrating complex systems, the expanded cost of extensive system software (now reaching 5-10 percent of total weapon system cost), and the failure to make effective use of common hardware and software standards to achieve cost savings.

Given the substantial DoD budget cuts to come, ways to mitigate the rising cost of avionics must be sought. The use of integrated system architectures, open system standards (including commercial technology), and commonality should provide relief.



Source: Reference [6].

Figure II-1. Avionic Cost Trends

B. RESPONSE TO CONGRESSIONAL MANDATE

In the 1987 DoD Appropriations Act, Congress specifically directed service representatives to prepare a joint plan for the inclusion of fully integrated, digital avionics, communications, sensors, embedded communications security, and other electronics on all major tactical aircraft being developed [7]. To respond to the congressional requirement, the Joint Integrated Avionics Plan (JIAP) was issued by the DoD. The plan was subsequently revised and issued in final form in March 1989. The Joint Integrated Avionics Working Group (JIAWG) was established in March 1987 by the Service Acquisition Executives in accordance with JIAP provisions.

The JIAWG was charged with developing an integrated avionics architecture. A set of supporting standards was to be developed as the common hardware/software building blocks to implement the defined architecture.

The language of the fiscal year 1990 Defense Appropriations Bill [8] reaffirmed the previous action and required that "the designs of the Army LHX [now the RAH-66], the Advanced Tactical Aircraft [the A-12 (P^3I)[1]], the Air Force Advanced Tactical Fighter [now the F-22], and any variants of these aircraft, must incorporate JIAWG standard avionics specifications no later than 1998."

The Tactical Systems activity within the Office of the Under Secretary of Defense Acquisition was to monitor progress in accomplishing the integrated electronics mandate. A key part of this responsibility was assuring implementation of the JIAP to achieve appropriate use of JIAWG technology in the designated developing aircraft systems.

During the competitive acquisition phase of the F-22 and RAH- 66 aircraft, JIAWG made good progress on general specifications and was able to issue the Common Avionics Baseline I (CAB-I) in May 1987. This was followed by CAB-IIA in June 1988, CAB-IIB in January 1989, and CAB-III in early 1990. The baselines contained general requirements, but lacked key final details. Final information was to be contained in CAB-IV—scheduled to have been issued in the third quarter of 1992—but the document has been delayed.

The early momentum of the JIAWG has clearly diminished as a result of the awards to the prime contractors. Some momentum was recently restored as a result of Office of the Secretary of Defense (OSD) efforts, and initial agreements have been reached on module connectors, power supplies, communications, navigation and identification (CNI) modules, and other common technology for the F-22 and RAH-66. However, many other changes are needed before common electronic modules can be widely used for both aircraft systems.

C. RECENT EFFORTS

1. Joint Services Review Committee/Joint Logistics Commanders

The Joint Logistic Commanders, through an ad-hoc Joint Services Review Committee (JSRC) organized in 1980, has pursued a program to develop standard avionic equipment. Major accomplishments include developing the Standard Central Air Data Computer, Standard Attitude/Heading Reference System, Ground Collision Avoidance Software, Standard Electronic Clock, and Flight Data Recorder Systems. These pieces of equipment have found application across the three services.

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[1] The A-12 was canceled in 1991 and replaced by the A/F-X, which was subsequently also canceled.

Current JSRC projects include the Downed Airman Locating System, Solid State Barometric Altimeter, Ground Proximity Warning System, Standard Compass System, and the Single Channel Ground and Airborne Radio System (SINCGARS or AN/ARC-210). Also, JSRC has investigated the possible application of JIAWG technology to existing aircraft.

2. Other Standards Programs

a. Military Programs

A number of other electronic development efforts within the services are formulating electronic hardware standards. Major efforts include:

- Standard Army Vetronics Architecture (SAVA);
- Electronic Module Signal Processor (EMSP), Navy;
- Modular Avionics System Architecture (MASA), Air Force;
- Multi-Application Avionics Computer (AYK-14), Navy; and
- Advanced Spaceborne Computer Modules (ASCM), Air Force.

Each of these programs is developing common integrated equipment/modules for a specific weapon system area. Although some of the programs are similar, little has been done to coordinate their technology developments [4].

Several other standards development actions in progress involve information processing and communications system interfaces and protocol standards (see section C in Chapter III). This work is being accomplished by the individual services and DoD agencies. Some of these initiatives were started only recently, and their effectiveness remains to be determined.

b. Commercial Programs

A wide range of electrical, electronic, communications, and data processing standards have been developed by several commercial standard organizations. Principal among the organizations are:

- Institute of Electrical and Electronics Engineers (IEEE),
- Society of Automotive Engineers (SAE),
- Electronic Industries Association (EIA), and
- American National Standards Institute (ANSI).

These organizations develop standards for use by commercial industry. The Department of Commerce, through its National Institute of Standards and Technology (NIST), has played a key role in these activities. The DoD has made use of the commercial standards and is increasing its efforts to work cooperatively to support future standards development.

Commercial airlines make use of commonality and open system standards as the basis for acquiring most of their avionic systems. The group of airline engineering representatives that forms the Airline Electronic Engineering Committee (AEEC) develops form, fit, and function (F^3) specifications for airline avionics. Aeronautical Radio Incorporated (ARINC), a communications company wholly owned by the airlines, serves as the secretary for the AEEC and issues the specifications as ARINC standards. The AEEC process, which has been functioning for over forty years, provides the airline industry a full range of avionic and supporting specifications and design guidance. Over the past fifteen years, the AEEC has upgraded its avionic technology to an almost completely digital basis. Recently, the airlines have embarked on forming an Integrated Modular Architecture (IMA), which will focus on using the latest high-speed computer technology to form highly integrated avionics architectures for aircraft.

The ARINC specifications are not mandated for use by the airlines. Rather, each airline is free to select equipment of its own choice. However, the equipment developed to ARINC specifications (at manufacturer's expense) has been high-performance and cost-effective equipment. Airline equipment is often acquired with long-term warranties, which provide feedback on product improvement and control of support costs. The success of the ARINC specification process is a result of the underlying economics and values.

D. MANAGEMENT ENVIRONMENT

The Defense Information Systems Agency (DISA) has been given the charter to develop and manage standards for DoD information technology. DISA will establish requirements for standards and, when necessary, prepare documents on information processing and associated communications.

Current DoD policy related to use of common integrated electronics in weapon systems as reflected in DoD Directive 5000.1 [9] and DoD Instruction 5000.2 [10] is not clear and could even be construed to be negative. To encourage commonality use, the language of basic DoD acquisition policy documents will have to be clarified, and new guidance should be provided to the services.

The role OSD plays in assuring the application of commonality across programs and services also needs to be clarified. Present OSD staff is most attuned to developing policy and supporting the Defense Acquisition Board (DAB) and budget processes.

Considering past congressional interest in the use of electronic equipment commonality, we expect pending DoD budget cuts to increase Congress's resolve to ensure broad application of common electronic equipment. It is highly possible that future direction may extend beyond the current scope of tactical aircraft to air, land, and sea weapon systems.

III. THE ESSENTIAL ELEMENTS OF AN ACQUISITION PROGRAM FOR COMMON INTEGRATED ELECTRONICS

IDA's previous studies [1 through 6] make it clear that an effective common integrated electronics program must consist of five essential elements:

- Integrated System Architecture: A set of electronic system architectures should be developed for various weapon system types to provide an enduring common design framework. The system architectures should be scalable to permit application to different size requirements.
- Advanced Technology Programs: Technology programs are essential to assure that system architectures, common modules, and system standards repre state-of-the-art capability.
- Open System Standards: Open system standards are needed to define system interfaces and the functionality of key components (modules). Families of standards will be required to meet the wide range of DoD weapon system needs.
- Standard Common Modules: Sets of standard electronic modules should be developed for use in deriving the defined system architectures. Use of common modules can reduce system development, acquisition, and operating and support costs.
- Management Policy and Organization: The development and application of coordinated common integrated architectures will not be effectively implemented without a strong management organization to create and monitor the commonality acquisition policy and processes.

The options available for each of these elements and their cost-effectiveness potential are examined in the subsections that follow.

A. INTEGRATED SYSTEM ARCHITECTURE

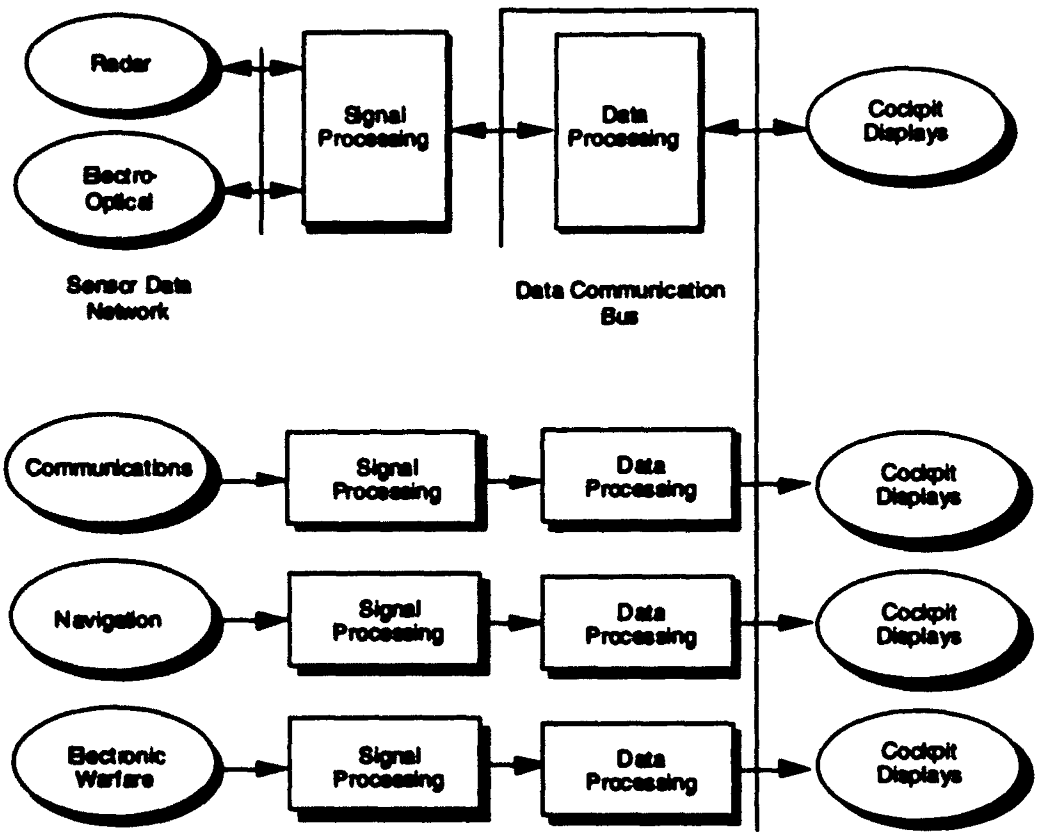
1. Architecture Concepts

The architecture for an electronic system defines the structural framework that will be used to create the functionality necessary to meet system requirements.

Electronic architectures can be cast in several basic forms:

- Federated—a concept in which key subfunctions (i.e., radar, electronic warfare, communication, navigation, etc.) operate independently, sharing only derived data.
- Integrated—an architecture structure that requires subfunctions to share common system units such as signal processors, data processors, displays, and so on.
- Hybrid—a combination of the federated and integrated architectures.

Figure III-1 illustrates a hybrid avionics configuration in which the radar and electro-optical sensor processing have been integrated and the remaining functions operate in a federated manner.



Source: Reference [2].

Figure III-1. Hybrid Avionic Architecture

No fully integrated digital electronic suite currently exists on any military weapons platform. Today's electronic system architectures can be characterized as hybrids (a combination of shared functions and independent functions). These hybrids represent an evolution from the federated architecture, which was a collection of individual functional units interconnected to form the total system.

Size scalability of an architecture concerns the ability of the design structure to accommodate applications of different scope. Scalable architectures permit the addition or deletion of basic building blocks (modules) to accommodate different magnitude applications while retaining standard system interfaces, signal structures, and operating characteristics.

2. Advantages

A highly integrated architecture facilitates more compact multifunction designs, providing weight and volume savings for a stated level of performance. Integrated design enhances the opportunity to incorporate redundancy and the ability to reconfigure in the event of a failure or change in operating mode. Weight and volume savings can translate into system life-cycle cost savings.

3. Disadvantages

Highly integrated systems can be more costly to develop, integrate, and test. This results from the increased number of system interfaces and the high degree of interaction that can occur among system elements. The software for highly integrated systems to carry out resource sharing, reconfiguration, and graceful degradation in the event of particular hardware failures can often be large, complex, and costly.

4. Cost Savings

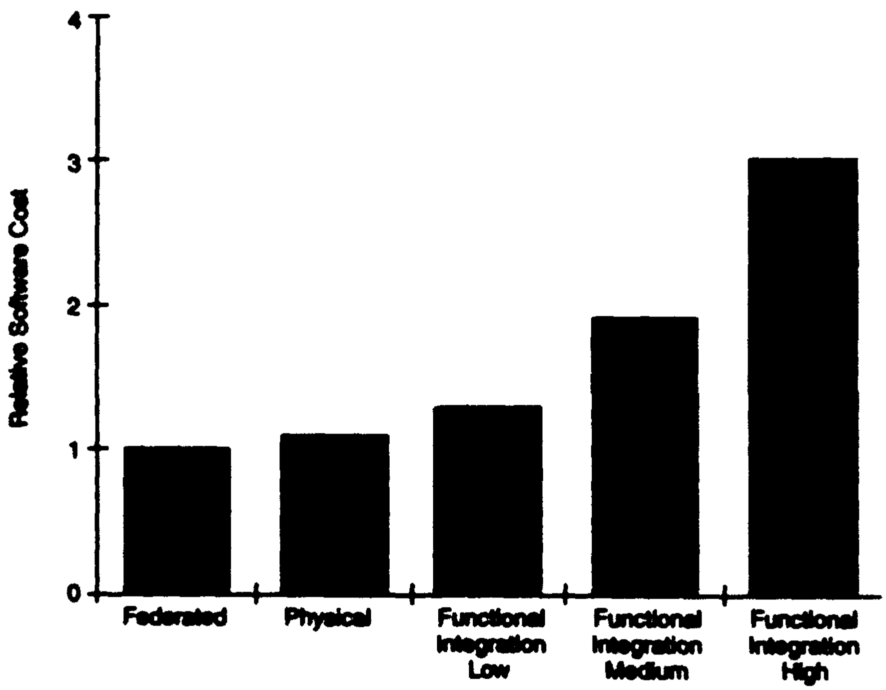
IDA conducted a study to determine the potential effect of system integration on the avionic suite for a hypothetical fighter aircraft similar to the Advanced Tactical Fighter [2]. The analysis focused on the use of federated and integrated processors for the major avionic functions: mission processing, fire control radar, infrared search and track, electronic warfare, navigation, communication and identification, and digital mapping.

The base case developed the weight, volume, and cost for a federated architecture. For the alternative, an integrated architecture was assumed that would consolidate the seven avionic processing functions into two computers.

The integrated architecture would reduce the weight of the avionic system. Analysis suggested that the acquisition cost of the two more complex processors would about equal the cost of the seven separate processors they would replace. The study indicated that the integrated processor configuration would thereby reduce aircraft gross takeoff weight. Total life-cycle cost savings were estimated for the physically integrated system and the federated system for a 20-year life cycle of a quantity of aircraft. Results indicated that savings could be realized.

The study also examined the impact of alternative levels of functional integration. Functional integration goes beyond physical integration and includes concepts such as system reconfiguration, resource allocation, and sensor data fusion. It was found that software costs can increase significantly for high levels of functional integration, transforming the projected life-cycle cost (LCC) savings into a loss.

Figure III-2 illustrates the relationship observed for the cases investigated. The federated system configuration formed the base and was assigned the value of 1 (LCC for complex avionic flight and support software was approximately $2 billion). The physically integrated case (two processors) yielded estimates of software LCC at 1.1 times the base cost. This case, coupled with the attendant weight savings previously described, provided significant cost savings. Employment of functional integration quickly increases the software LCC, eroding any LCC savings to be derived from the weight-cost reductions.



Source: Reference [2].

Figure III-2. Software Costs of Integration

5. Issues

Integration of system subfunctions can clearly produce weight and hardware cost savings. However, the impact of added complexity and attendant higher software cost should clearly be considered before adopting system requirements that call for high levels of functional integration. Development and adoption of families of scalable integrated system architecture can serve the DoD well by providing common design frameworks and standard system interfaces.

B. ADVANCED TECHNOLOGY PROGRAMS

1. Technology Flow

Over the past 40 years, significant technology development has taken place in the DoD, the National Aeronautics and Space Administration (NASA), the Department of Commerce, the Department of Transportation, and commercial industry. During the 1960s, the DoD provided much of the funding for development of solid-state and integrated-circuit components. NASA, through the space program, contributed to real-time computer and guidance system technology in the late 1960s and the 1970s. During this period, the private sector benefited from these developments through technology transfer programs [6].

As a result of the huge increases in the commercial computing market and the decreases in the DoD budget, both in total dollars and as a percentage of the gross national product, the DoD is no longer the dominate player in the 1990s electronics market. Current estimates place the DoD consumption of electronics at less than 10 percent of the total market. As a consequence, much of the development of technologies for large-scale information processing is now being directed at the commercial market rather than the DoD.

Fortunately, the DoD can use some commercial electronic developments in its weapon and business systems. Technology of interest includes items such as microprocessors, data buses, and software. In addition, some commercial products are of sufficient reliability and ruggedness that they can be used directly in some DoD system applications. More insight is needed about the utility of this technology for DoD applications and about how the DoD can best benefit from such developments.

2. Advanced Technology Demonstrations

Advanced technology developments, demonstrations, and prototype test beds are needed to investigate those unique DoD system technology areas that will not be addressed by the private sector. Such programs may be directed at developing new technology, adopting and modifying commercial technology, and/or validating new system concepts.

Over the past decade, attempts have been made to develop standards and common equipment and modules. These attempts have met with varying degrees of success and have ranged from small technology development projects to major billion-dollar development and acquisition programs. Examples of successful efforts are:

- VHSIC—a DoD initiative implemented through the three services to develop a new generation of Very High Speed Integrated Circuits (VHSIC) for application in military weapon systems.
- Common Module FLIR—the common module Forward-Looking Infrared (FLIR) was developed under the leadership of the Army Night Vision Laboratory. The program established a functional architecture and common modules that became the basis for FLIR equipment now used by all three services.

Both of these efforts had the objective of developing new system architecture and associated technology.

The Advanced Research Projects Agency (ARPA) is developing a massively parallel processing architecture in the High Performance Computing and Communications (HPCC) program. The architecture is based on the development of several building blocks (nodes) that can be joined together in a scalable manner to derive alternative levels of parallel computing capacity. The blocks being developed include a processor node, an asynchronous network interface node, and an intercommunication node.

The HPCC program expected to demonstrate 10-100 giga (10^9) processor operations per second in 1992. The ultimate goal is to achieve tera (10^{12}) operations per second by 1996.

A companion ARPA project is the development of new software concepts under the Advanced Software Technology and Algorithms (ASTA) program. ARPA's focus for ASTA is the development of algorithms and tools to facilitate parallel processing. These efforts include the development of the MACH (2.0, 2.5, and 3.0) real-time operating system that will find application for parallel processing.

The development of parallel processing will accelerate the growth in computer processing speed. The availability of this greater computing power will provide the means to obtain even greater weapon system functional capabilities. Since the ARPA parallel architecture is based on common building blocks, there will be an opportunity to achieve economy of scale through multiple applications of the common units. This can be achieved only if the architecture is implemented using open system standards to describe system interfaces, computer instruction sets, and support environments.

3. Technology Growth and Standards

Digital technology capabilities have been growing rapidly and show no sign of near-term abatement. Standards can have the effect of freezing technology at the point in time when they are issued. Given the time it often takes to develop and select a standard, standards may be nearly obsolete at issue. To avoid this problem, it is paramount that a vigorous coordinated technology program be established to provide the basis for future technology architectures and standards.

A critical DoD technology need is the requirement for a fully capable real-time operating system that could meet the needs of avionic and similar weapon system applications. Although work is being done (POSIX and MACH), it is important that this effort be given proper funding and priority. The proper operating system standards will have payback in the forms of application software reuse and the ability to upgrade fielded systems with faster, more capable technologies.

C. OPEN SYSTEM STANDARDS

1. Definition

IEEE document P1003.0 defines an open system as, "a system that implements sufficient open specifications for interfaces, services, and supporting formats to enable properly engineered components to be utilized across a wide range of systems with minimal changes, to interoperate with other components on local and remote systems and to interact with users in a style which facilitates user portability." "Open" in the definition translates to non-proprietary, fully disclosed standards.

2. Past Practices

The development of a highly integrated complex system such as tactical fighter avionics, requires a well-structured architecture that can meet the operational real-time performance requirements. In the past, avionic architectures have been developed by the system prime contractors and often contained company proprietary concepts that were tightly held and were often unique to each aircraft design. This resulted in duplicated research and development plus incompatibility among major subsystems creating high production costs, support, and system upgrade problems.

3. Concept of Operation

The open system concept implies that the key system interfaces and services would be derived from non-proprietary industry standards. This would permit a number of manufacturers to design subsystems that would interoperate with the central system. Openness promotes competition and reuse of subsystem components, both hardware and software, across several systems, thus providing cost savings. The development of an open system concept has the potential to ameliorate manufacturers' proprietary problems [6].

Open system concepts, when applied to computer technology (both hardware and software), provide the means for processor interchangeability and application software portability. Processors developed to open system standards with common instruction sets, standard input/output, and support service functionality can be interchanged. Older and slower processors, developed from prior technology can be replaced with minimal effort by faster processors built to the same open system standards. With processor technology doubling its capability every 18 months, the ability to make such upgrades is essential.

The open system concept permits existing software programs to be transported readily across platforms provided the processors are (1) equipped with common operating systems, (2) host the required program compilers, and (3) have compatible instruction sets and support environments. The availability of the design interface information is essential to permit multiple computer manufacturers to develop the needed compatible environments.

The key to establishing an open system concept is to select the appropriate level for system interface standards. If set too low, the ability to change out technology may be restricted. If standards are set too high, too little control over system inter- and intracommunications will be provided. Successes such as the IBM PC-compatible computers should be studied to draw guidance for future development of DoD open system standards.

4. Standards Development

The creation of an open system requires the development of an underlying system architecture that has the capability to meet a range of application requirements. To facilitate architecture development, reference models are often established that describe the basic system structure. Reference models typically define the generic processing and inter- and intrasystem communication in terms of standards for message formats, protocol for data transmission, internet addressing, and physical/electrical connections.

Open systems architectures are being developed in commercial industry for data communications between computers and workstations via local and wide area networks. The open system defines system interfaces, not the computer design. The Open System Interconnection (OSI) is an intercomputer communication standards effort that has received support from both government and industry. Properly conceived, open systems provide a framework for system designs that are insensitive to many changes in technology.

Given the scope of commercial industry electronic and data processing technology developments, it is important that the DoD utilize these resources. This can be accomplished by letting industry know what DoD needs are so that they can be considered during technology and standard developments. By securing industry standards that reflect DoD needs, more affordable DoD programs may be secured by using commercial technology.

In addition to the programs cited in Chapter II, several other initiatives are addressing electronics standards:

- Next Generation Computer Resources (NGCR)—a Navy-led effort to establish standards capable of meeting the Navy's mission-critical computer resource requirements.
- Open Systems Architecture Working Group—an initiative to develop open system architecture and specifications for DoD systems.
- Corporate Information Management (CIM)—a DoD initiative to improve the processing infrastructure to improve DoD's ability to provide centralized resource management and planning service.
- Copernicus—a Navy initiative to develop a comprehensive user-oriented command and control information management architecture and technology.

Each of these efforts focuses on a subset of the total DoD weapons complex. As a consequence, some duplication of effort results in the development of similar, but non-interchangeable electronic standards (e.g., modules). Stronger DoD management of these technology development efforts could lead to broader based electronic common standards, thus avoiding duplication expense.

5. Life-Cycle Cost Implications

Decisions regarding families of standards should be addressed from the standpoint of the full life-cycle cost and should consider the effect on system development, production, maintenance, and support equipment. Technology decisions that seem correct from a design standpoint may not be appropriate when considered from a full life-cycle standpoint. For example, technology selected because of low acquisition cost may be very costly to support over the system's life cycle.

6. Issues

As previously noted, a number of service, DoD, and other government organizations are working technology standards issues. To be effective, it is essential that these efforts be focused and directed in a logical and coherent manner to assure compatibility and to avoid duplication. To assure that the proper focus and coordination are achieved, it is important that OSD take a stronger role in both setting standards policy and in approving key standards that will affect the DoD.

DoD should support standards, but should not mandate a single set of standards for all applications for there is a spectrum of requirements that cannot be met by a universal solution [6]. Rather, families of standards are needed to cover the broad scope of applications likely to be encountered in the full range of DoD systems. It is important that the real-time performance requirements of DoD weapon systems be considered in the development and selection of technology standards.

D. STANDARD COMMON MODULES

1. Definition

The JIAWG defines commonality broadly as an item or items that may be used to accomplish equivalent functions in multiple applications. The definition applies to both hardware and software commonality and includes both built-to-print (exact duplicates) and form, fit, function, and interface (F^3I). Commonality may occur within a weapon system program or across multiple programs (weapon platforms).

Table III-1 illustrates the factors that determine if modules are interchangeable. These factors may be viewed as a series of levels that must be compatible, beginning with the physical form and ending with the detailed design.

Compatibility of the first four levels shown in Table III-1 provides functional F^3I interchangeability. To achieve full built-to-print benefits, it is necessary to add the final level, which dictates use of the same detailed design.

Table III-1. Electronic Compatibility Factors

Level	Factor
Physical	Board form, connector type, cooling system
Electrical	Supply voltage, current requirements pin-out, and power
Communications and Control	Input/output standards, protocol, message format, and signal standard
Application	
Functional	Action(s) performed by the module, i.e., processor, A/D converter, etc.
Performance	Speed, accuracy, response time, capacity, reliability, and maintainability
Environment	Capability of the module to perform when subjected to temperature, vibration, etc.
Design	Circuits, materials, parts, layout, etc.

2. Advantages

The implementation of a broad-based, coordinated commonality program reduces development cost by the elimination of design duplication. This permits limited research and development (R&D) dollars to be focused on the development of critical-mission technologies.

Use of commonality can have the added benefits of improving system interoperability and facilitating system integration. The availability of standard data buses, communication controllers, data and signal processors, local area network interface devices, memory modules, and power supplies should significantly reduce the design and test efforts to integrate a weapon system. Standard hardware components also provide an opportunity to reuse software associated with the common components, thus avoiding added software development, test, and support.

Application of a common module requires only that the module functionality be suitable and the module interface be designed and tested. As a consequence, the engineering and test efforts required to employ common modules can be significantly less costly and have reduced technical performance risk.

The greater use of common modules provides lower production costs through the economy of scale resulting from learning curve savings. Since the production base of future weapon systems will most likely be limited to a few hundred systems, savings can accrue through the larger production base achieved by pooling requirements for common modules across several weapon system programs. Common modules also provide a maturation process for electronics needed to realize their full performance and reliability potential.

Lower support costs result from use of commonality by producing reductions in the investment in spares, achieving economies through the use of common test equipment, and using shared software support facilities permitted by software reuse.

3. Disadvantages

Some have suggested that use of commonality for military applications locks in technology and does not permit new system designs to take advantage of the latest developments. This can occur if the common modules/components are not periodically updated. An aggressive, well-funded commonality program that continuously upgrades its technology base would avoid obsolescence.

It is generally held that the use of common or standard equipment costs "technically" (results in reduced technical performance), which will result in a less than optimum configuration with weight and performance penalties. It is further suggested that the use of emerging standards can carry the added risk of timely availability. Because of these prevailing conceptions, program managers have been considered to know what was best for a specific system and have received little interference in their system technology implementation choices.

Clearly, standard components should be used when technical and cost analysis determines their suitability; they should not be used when they are found to be inappropriate. Commonality application analysis should consider the full effect on life-cycle costs of technology choices on the system user, not just the incremental cost to the designer-producer. The implications of commonality across programs should also be considered.

The development and maintenance of an effective system of commonality standards constitutes a significant administrative burden. The recent Joint Integrated Avionics Working Group (JIAWG) effort to develop a set of standards for common avionics for the ATF (F-22), A-12, and the LH (RAH-66) is an example of the staffing and management resources necessary. To be effective, a commonality program must be directed by a manager who has decision authority and budget control to develop the required technology base and secure its appropriate application in designated weapon platforms.

Contractors developing weapon systems are often motivated by profit to use their own off-the-shelf designed and manufactured hardware. This follows since the production phase of a system acquisition program typically provides the greatest profit return. Using common modules developed and manufactured by another company would reduce the system developer's profit potential. Conversely, manufacturers are more inclined to use common modules if they are the manufacturer.

4. Cost Savings

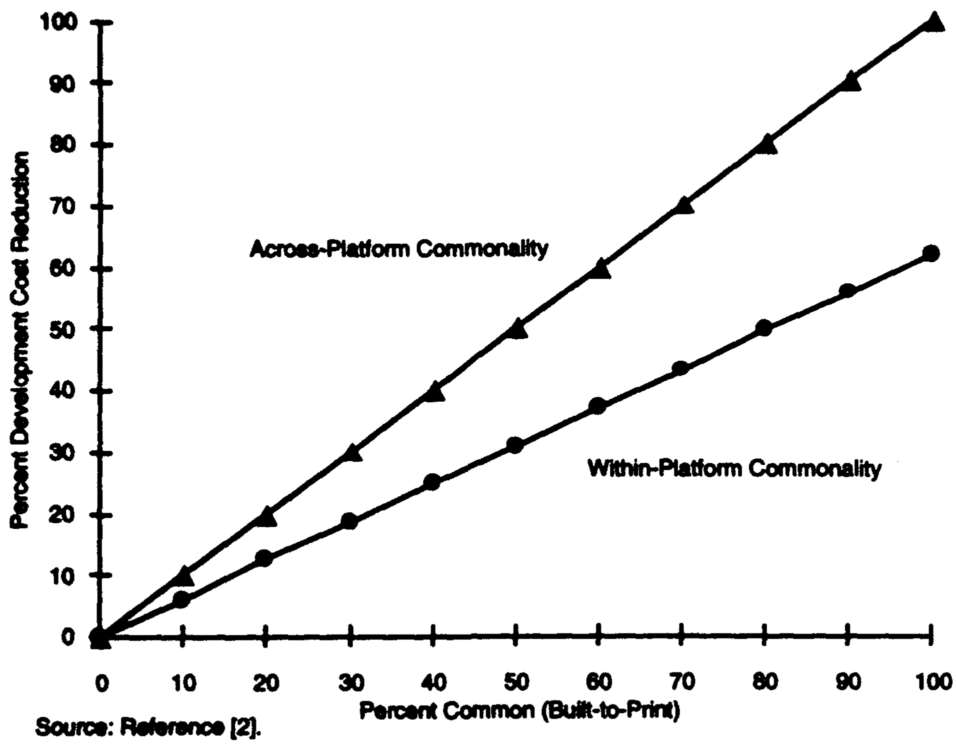
Opponents of commonality suggest that commonality produces little savings and, considering other potential disadvantages, question the validity of standards use. In a previous study, IDA found that commonality could provide significant cost savings across the system life cycle [2]. The study investigated the potential cost savings from avionics commonality when applied to aircraft such as the ATF, LH, and A-12.

IDA found for the example studied (avionics core processing with 90-percent commonality) that savings of 57 percent on development cost and 2 percent on production cost could be achieved. Introduction of a second program with similar characteristics that would use the same modules, would produce combined development savings of 77 percent and production savings of 17 percent. For the total avionic suite, 50-percent commonality within platform provides savings of 33 percent for development and 1 percent for production. Across-platform commonality yields savings of 27 percent for development and 9 percent for production.

Figures III-3 and III-4 present the relationships observed by IDA for development and production quantities. The percentage savings cited can provide significant returns when applied to a combined $10-billion to $20-billion cquisition program for avionic modules. The combination of built-to-print and within-s stem commonality provides the best cost saving opportunity; the combination of F^3 and across-system commonality provides the least cost savings opportunity.

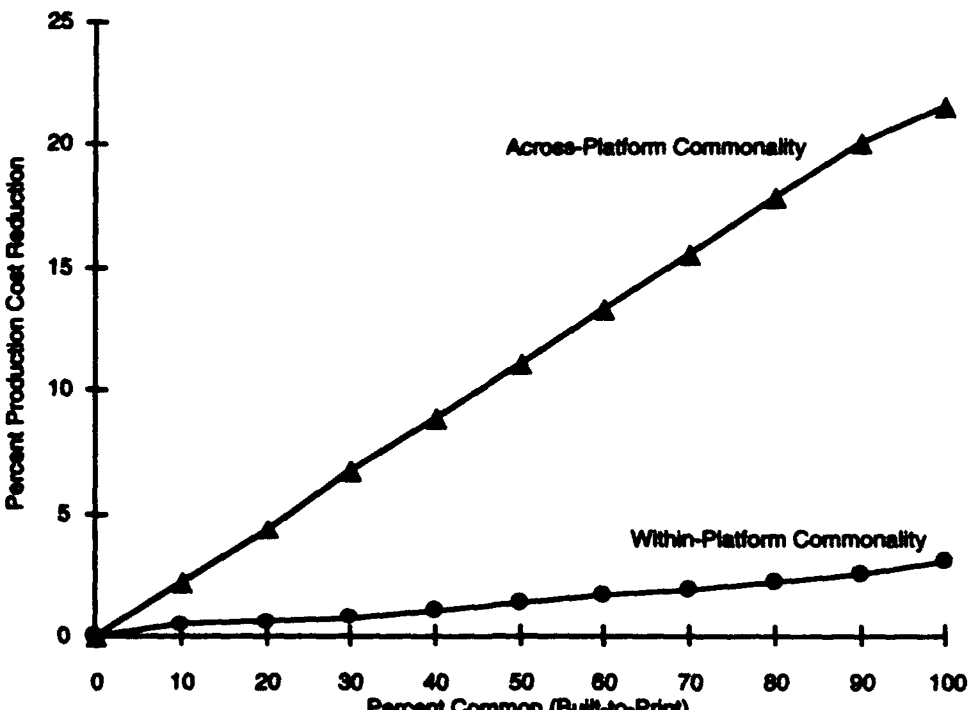
5. Issues

The need to consider commonality at this time is clearly based upon weapon system affordability. Given pending budget cuts, DoD can no longer conduct "business as usual" in the development of weapon systems. Commonality, already recognized by Congress and others as a cost-saving strategy, will continue to receive attention. Commonality must be implemented across weapon programs if it is to reach its full cost-saving potential. Service and OSD organizational constraints seem to be a major barrier for commonality use across programs and services.



Source: Reference [2].

Figure III-3. Commonality Versus Development Cost: Core Processing



Source: Reference [2].

Figure III-4. Commonality Versus Production Cost: Core Processing

Within-platform commonality is more readily achieved than across-platform commonality because it can be required by the engineering and manufacturing development (EMD) contracts and is generally consistent with the contractor program manager's objectives. Across-platform commonality requires coordination across program offices and makes program managers dependent on technology that may be outside their immediate control.

DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures" [10], supports the program manager by noting that "standards should *not* be applied in an acquisition program before the system concept has been fully explored." It further adds that "standards should be considered, but *shall not* overly constrain the early analysis of design options."

In the current defense budget environment, it will be essential that the technical "price" of using common items be carefully evaluated in relation to the full life-cycle cost savings implications. The ability of common items to ease system integration, allow reuse of software, avoid development duplication, lower production cost, and reduce support cost must be fully weighted against some inefficiencies (weight, performance, volume, etc.) that may be introduced by utilizing standard items.

Use of properly structured EMD contract incentives may provide the means to effectively secure both within- and across-platform application of common integrated electronics. The LCC savings that can be achieved by the use of common integrated electronics should provide a significant return on the investment made in incentive payments.

E. MANAGEMENT POLICY AND ORGANIZATION

1. Policy

As previously noted, the current DoD policy on common integrated electronics as reflected in DoD Directive 5000.1 [9] and DoD Instruction 5000.2 [10] is not clear. To place greater emphasis on commonality use, clear language will be required for the basic DoD acquisition policy documents and new guidance should be provided to the services.

2. Organization

The responsibility within OSD for achieving the congressional mandate (JIAWG) rests with the Under Secretary of Defense Acquisition/Tactical Systems (TS). This responsibility is currently being accomplished through the Conventional Systems

Committee (CSC)/DAB review process, supplemented with ad hoc oversight as dictated by day-to-day issues. Although DISA is charged with managing information technology, no staff or program office is specifically assigned the responsibility to secure electronic commonality application across weapon platforms.

The benefits and costs associated with the creation of an organization within OSD to oversee commonality development and application can vary widely, depending on the role and authority given. A previous IDA study postulated a range of organizational options that varied from no change through increasing levels of management oversight to one which would consolidate all major weapon electronics programs under a separate Defense Acquisition Agency [5]. The options were:

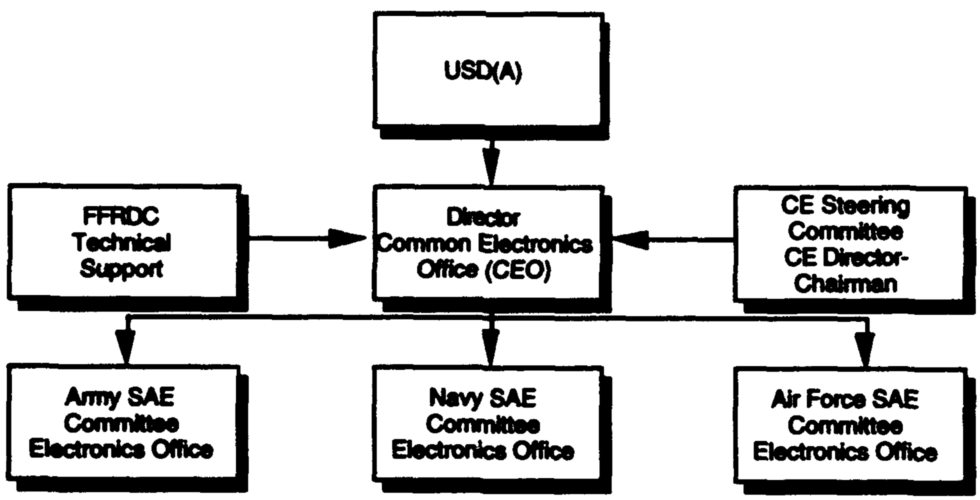
- No Change: TS would continue its oversight of commonality applications to tactical weapons on an ad hoc basis through the CSC/DAB review and the annual budget process. This option is expected to achieve a modest degree of electronic commonality within programs, but have limited impact on the more difficult across-platform applications.
- Minor Change: A staff specialist for commonality would be designated and assigned to TS. The specialist would interface with the Service Acquisition Executives (SAEs) to promote and coordinate commonality within and across tactical programs. Adoption of this option should lead to the use of commonality across air, land, and sea platforms, along with better coordination of technology development programs.
- Moderate Change: A Common Electronics Office (CEO) would be formed within TS modeled after the VHSIC program. The CEO Program Director would formally interface with service SAEs on commonality issues and approve selected R&D funds to form a commonality technology base. The establishment of a more formal infrastructure for commonality should improve applications across all tactical weapons programs.
- Significant Change: A CEO would be established as above, but at the Under Secretary of Defense Acquisition [USD(A)] level. This organization option would address commonality for all weapon electronic systems. Over the long term, electronic commonality should be achieved across tactical and strategic weapon programs. Significant cost saving should accrue from broader use of commonality.
- Major Change: Within the Office of the USD(A), an Assistant Secretary of Defense for Electronics would be created to form a directorate for weapon system common electronic programs across all services. Major investments would be required to implement this more sweeping change, but significant savings could be expected in the long term.
- Extensive Change: Under the USD(A), create an agency to manage the acquisition of electronics for all major DoD weapon programs. Extensive reorganization would be required throughout the DoD, resulting in civilian

direction and management of all electronic programs. This option would provide an opportunity to significantly consolidate service system programs, laboratories, and test facilities, while producing a broad-based technology program.

A review of several analogous organizations could provide guidance in selecting the appropriate option. For a more limited initiative, the VHSIC program could provide guidance in selecting the appropriate option. VHSIC was created as a program office within the Office of the Director, Defense Research and Engineering (DDR&E) and was a coordinated technology development program through the services' R&D organizations. It produced an array of advanced state-of-the-art digital technology that is now finding application in a broad range of weapon systems.

On a larger scale, the Defense Information Systems Agency or Defense Nuclear Agency could offer precedents. Each agency is charged with developing technology within its field of specialty. Further explorations of these precedents may be warranted to gain full insight regarding the proper alternative to pursue for broader electronic commonality application.

One option that would provide a reasonable degree of oversight would be the creation of a CEO within USD(A). The structure of the CEO is illustrated in Figure III-5. The CEO under this option would be able to apply management oversight to achieve commonality for air, land, and sea tactical weapons, which constitute a major segment of the DoD budget.



Source: Reference [5].

Figure III-5. Proposed Structure of a Common Electronics Office

IV. CONCLUSION

This report has summarized the DoD electronic commonality opportunities and challenges that have been identified by the series of studies on common integrated electronics conducted by IDA during 1989 through 1992 [1 through 6]. These studies were supported and guided by the Under Secretary of Defense (Acquisition and Technology)/Tactical Warfare Programs.

The overall conclusion to be drawn from these studies is that a significant measure of electronic system cost control can be achieved by implementing a broad, comprehensive common integrated architecture program. We therefore recommend that a common integrated architecture initiative be undertaken that addresses all the essential elements we have identified (i.e., system architecture, advanced technology programs, open system standards, standard common modules, and effective OSD oversight). The scope of elements should include:

- Integrated System Architecture: Create for classes of key defense systems, standard integrated architectures to provide the essential framework for cost effective systems acquisition, operation, and support.
- Advanced Technology Programs: DoD advanced technology development, demonstrations and prototype test beds are needed to address those unique defense system technology areas that will not be covered by the private sector. Commercial technology components, however, must be used wherever possible to avoid development of more expensive unique military parts. Top priority should be given to developing open system standards for parallel processing and a fully capable real-time operating system.
- Open System Standards: It is important that the DoD make full use of open system standards. DoD should support standards, but not mandate a single set for all applications. Rather, families of standards are needed to cover the broad scope of DoD systems. It is also important that the DoD use commercial industry electronic and data processing technology developments. This can be best accomplished by working with industry to advise them of DoD needs such that they will be considered during technology and standards development.
- Standard Common Modules: Support the JIAWG initiative for it represents the start of a potentially significant standard common module program. Coordinate and encourage other common module program, i.e., SAVA, ASCM, et al.

- Management and Policies: To achieve a common integrated electronics program, leadership needs to be provided from the top level of OSD. Direction should come from a level that can provide oversight of decisions related to the services and defense agencies expenditures of 6.2 and 6.3 funds and authority and responsibility over 6.4 funds. Contractual means must be developed through program incentives to achieve standard common module application within and across future weapon system developments.

Achievement of effective common integrated electronics acquisition requires that a complete program be in place that provides the complete set of essential elements. The set includes system architectures, common modules, standards, advanced technology program, and an effective management policy and organization for guidance. A common integrated electronics initiative that does not address all these elements is almost certain to fail. Implementation of a full common integrated electronics program has the potential to produce significant electronic system LCC savings. To assure that the proper focus and coordination is achieved, it is important that OSD take a stronger role in both setting standards policy and in the approval of key standards that will impact all of DoD.

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REFERENCES

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[10] DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures." February 23, 1991.

ABBREVIATIONS

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AEEC	Airline Electronic Engineering Committee
ANSI	American National Standards Institute
ARINC	Aeronautical Radio Incorporated
ARPA	Advanced Research Projects Agency
ASCM	Advanced Spaceborne Computer Modules
ASTA	Advanced Software Technology and Algorithms
C^3I	command, control, communications, and intelligence
CAB	Common Avionics Baseline
CEO	Common Electronics Office
CIM	Corporate Information Management
CNI	communications, navigation and identification
CSC	Conventional Systems Committee
DAB	Defense Acquisition Board
DDR&E	Director, Defense Research and Engineering
DISA	Defense Information Systems Agency
DoD	Department of Defense
EIA	Electronic Industries Association
EMD	engineering and manufacturing development
EMSP	Electronic Module Signal Processor
F^3	form, fit, and function
F^3I	form, fit, function, and interface
FLIR	Forward-Looking Infrared
HPCC	High Performance Computing and Communications
IDA	Institute for Defense Analyses
IEEE	Institute of Electrical and Electronics Engineers
IMA	Integrated Modular Architecture
JIAP	Joint Integrated Avionics Plan
JIAWG	Joint Integrated Avionics Working Group
JLC	Joint Logistics Commanders
JSRC	Joint Services Review Committee
LCC	life-cycle cost

LH	light helicopter
MASA	Modular Avionics System Architecture
NASA	National Aeronautics and Space Administration
NGCR	Next Generation Computer Resources
NIST	National Institute of Standards and Technology
O&S	operating and support
OSD	Office of the Secretary of Defense
OSI	Open System Interconnection
P^3I	Pre-Planned Product Improvement
R&D	research and development
SAE	Society of Automotive Engineers *or* Service Acquisition Executive
SAVA	Standard Army Vetronics Architecture
SINCGARS	Single Channel Ground and Airborne Radio System
TS	Tactical Systems
USD(A&T)	Under Secretary of Defense (Acquisition and Technology)
VHSIC	Very High Speed Integrated Circuits